Classification of Urban Heat Stress Intensity and Population Affected by Heat Stress in The Niger Delta Region of Nigeria

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Abstract- ***This study examines the spatial and temporal characteristics of urban heat stress in the Niger Delta, with the objectives of establishing the relationship between ambient air and land surface temperature while modeling the urban heat stress intensity and classifying the different levels of heat stress and determine population affect by the different the heat stress class within the study are. Quantitative methods and correlation research design was used for this research, while this study used Pearson Product moment Correlation Coefficient, ANOVA, dispersion and other statistical tools to analyze the data generated from primary and secondary sources. The sample population was 7 states size while the sample size was 13 to 15 samples in each of the studied states. The results showed land surface temperature significantly correlated with ambient temperature in Bayelsa and Akwa-Ibom State. Port Harcourt Rivers State recorded the highest land surface temperature at point 10 Trans Amadi industrial Layout, with a value of 37.33^{o}C, the lowest was at point 6, with a value of 26.25^{o}C. Uyo city recorded highest land surface temperature at Point 7 Oron Road,with a value of 30.62^{o}C, Bayelsa state, Yenagoa satellite map temperature minimum of 0-22.30 and maximum of 45.67-53.42 ^{0}C in the dry season, Calabar Cross River state recorded temperature values of 7.87 -14.02^{0}C, Edo Benin city Land Surface Temperature LST. Variations of 4.73 - 11.80 ^{0}C, 11.81 -18.89^{0}C and 18.90-25.98^{0}C, Imo state Owerri dry season showed temperature variations between 0-16.99^{0}C,17.00-23.92 and 30.85.77^{0}C, Port Harcourt city in the wet season varied from 7.86 -32.51^{0}C. The study concluded that Port Harcourt, Benin, and Yenagoa, have higher SUHII intensities while Calabar, Uyo, Owerri have moderate SUHII, Port Harcourt, Uyo and Benin have temperature class of 3-5 and 1 -2 which is very weak UHI at the outskirt of the city. The study also recommends that in order to contribute to the sustainability of the urban environment, there is need to expand some of the cities to decongest them and create more greener cities for comfortable habitation and infrastructural projects like airports, industrial etc. should be sited in rural area to mitigate urban heat stress.***

Key words: Urban Heat Island Class, Urban Heat Island Intensity Model, Population Risk.

I. INTRODUCTION

Urban heat stress is a growing concern worldwide, particularly in densely populated and rapidly urbanizing regions. The Niger Delta, a prominent and ecologically sensitive area in Nigeria, faces unique challenges in this regard. Characterized by its diverse ecosystems and significant oil production activities, the region is experiencing substantial environmental changes that exacerbate the effects of urban heat stress (Akpan and Ogunjobi,2017). Understanding the intensity of urban heat stress and the population affected by it is crucial for effective urban planning and public health strategies. This study aims to classify the intensity of urban heat stress across different urban centers in the Niger Delta and assess the population at risk. By integrating climatic data, demographic information, and spatial analysis techniques, the research seeks to provide a comprehensive overview of the current state of heat stress in the region (Ayanshola, Suleiman and Salami, 2020).

The findings from this research will contribute to developing targeted interventions to mitigate the adverse effects of heat stress, ensuring the well-being of the Niger Delta's urban population and fostering sustainable urban development. This study's insights are particularly relevant in the context of global climate change, which is expected to further amplify heat stress in vulnerable regions like the Niger Delta. This study aims to classify the intensity of urban heat stress across different urban centers in the Niger Delta and assess the population at risk. By integrating climatic data, demographic information, and spatial analysis techniques, the research seeks to provide a

comprehensive overview of the current state of heat stress in the region. Heat stress classification involves categorizing the severity of heat-related conditions based on specific thresholds of temperature (Ede and Edokpa,2015).

II. MATERIAL AND METHODS

The Study Area

The location and extent of this study is the Niger Delta Region of Nigeria, this geopolitical zone is graphically located on the following coordinates Lat: 5°19' N and Long:6°28' E, consists of 9 states, the states are known geographically as the Niger Delta Region in Nigeria (Fig. 1) with Anambra State as neighbour in the south eastern area, Atlantic Ocean in the south, Ekiti and Osun states in the south west. One of the things these states have in common is that they have the keys to the Nigeria economy, being the states with major oil and gas producing states in Nigeria, the states comprise of the following states: Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Abia, Imo, Ondo and Rivers.

The region experiences the humid tropical climate, which is characterized by wet and dry seasons, this region is rich with crude oil which provides the major economic lame stream of the country. It also constitutes a reasonable number of Nigeria's population (Ukhurebor & Abiodun, 2020). The variations in rainfall in this region can significantly affect agricultural activities as most local farmers in this region depend on favourable weather condition during agricultural activities, from sowing to harvesting. The climate condition also plays crucial roles in determining agricultural yields (Araya *et al.,* 2012; Audu *et al.,* 2012; Bhandari, 2013; Muluneh., 2017). With effects on other human activities, this is evident in the destruction of some plants by soil erosion.

The Niger Delta region has several ecosystems that play essential role for the sustenance of the different habitats and life forms in the area, some of the notable ecosystem includes freshwater swamp forest, lowland rainforest, mangroves forest etc. (Izah, 2018). In recent time, the rate of deforestation, excessive hunting of wildlife, bush burning, and intensive agricultural practices has increased in the region, the vegetation type around the Niger Delta can be classified as; the lowland rainforest which is among the complex ecological zones in the region with regards to diversity of species.

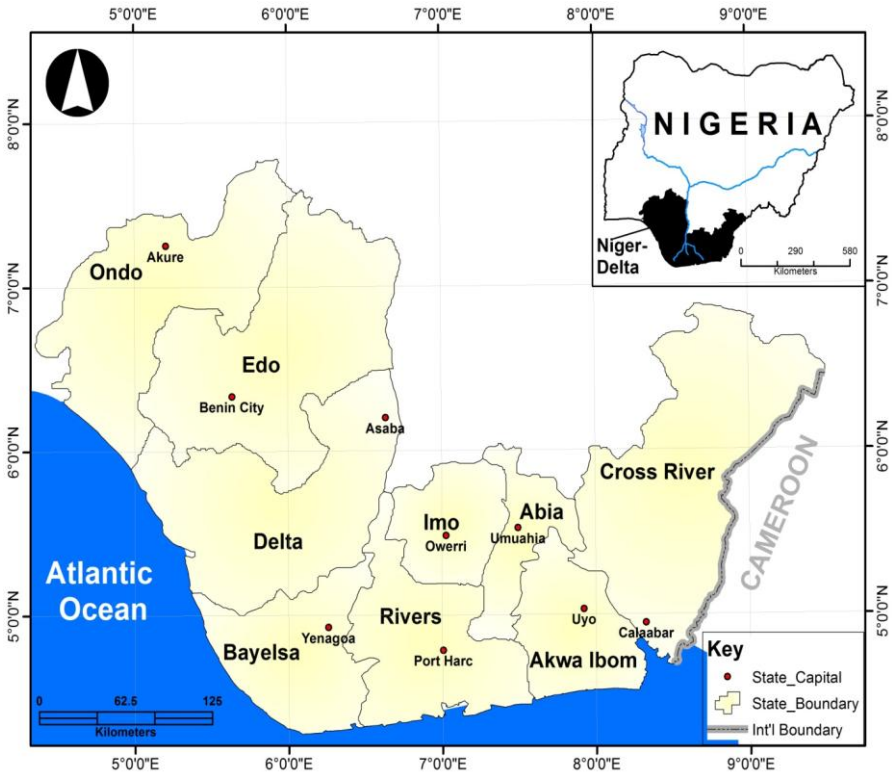

Figure 1: Study Area: Niger-Delta Region of Nigeria

Sampling Techniques

Quantitative research method was used in this research, the reason is that in quantitative research, statistical analysis necessitates the reduction of phenomena to numerical values. With variables being crucial to quantitative research because it is the phenomenon that is categorised and measured. The focus of quantitative methods is on objective measurements and the statistical, mathematical, or numerical analysis of data gathered through surveys, polls, or by employing computational tools to modify statistical data that has already been obtained. The quantitative technique involves gathering and evaluating numerical data in order to provide answers to scientific research enquiries. Meteorological equipment was used for the ground station data gathering exercise within the study area. The monitors were mounted to a height of 6 meters above the ground level in an open space to avoid ground level interference, the instrument was allowed to take samples at the study sites on the day the satellite system Landsat 8 over pass of the study area). In this study, the first step was followed and the Landsat data was computed using the method proposed by Avdan and Jovanovska (2016), which involves:

I. Computation TOA (Top of Atmospheric) spectral radiance
II. Conversion of TOA to Brightness Temperature conversion
III. Calculation of the NDVI
IV. Calculation of the proportion of vegetation
V. Calculation of Emissivity
VI. Calculation of the Land Surface Temperature

LST = (Brightness Temperature T / (1 + (0.00115 BT / 1.4388) Ln (Emissivity)

The Urban Heat Island (UHI) Intensity was computed using the method proposed by Hsu et al. (2021). The method was adapted by selecting a reference rural area nearby each city and subtracting the LST for this reference rural area from the LST for the urban areas LST.

The Urban heat Island intensity classification was produced by reclassifying the UHII maps using the Jenks (1967) natural break algorithm. 5 classes were created for each city, 1 least and 5 the worst UHII. The population at risk of different classes of UHII were computed using the gridded population data produced by Bondarenko *et al.* (2020). The population within each class were calculated and a table was produced.

III. RESULTS

The surface urban heat Intensity Class for years, 2020 -2022 within Asaba metropolis in (Figure 2) showed the city centre to have class 4 and 5 heat stress which can be said to be strong and very strong heat stress, the temperature difference between the urban centre and the rural area is high, with heat stress arising from temperature values of 5.57-6.97^{0}C. Compared with the strong heat stress value 0.16-0.19^{0}C and very strong heat stress with temperature values of 0.19-.036^{0}C.

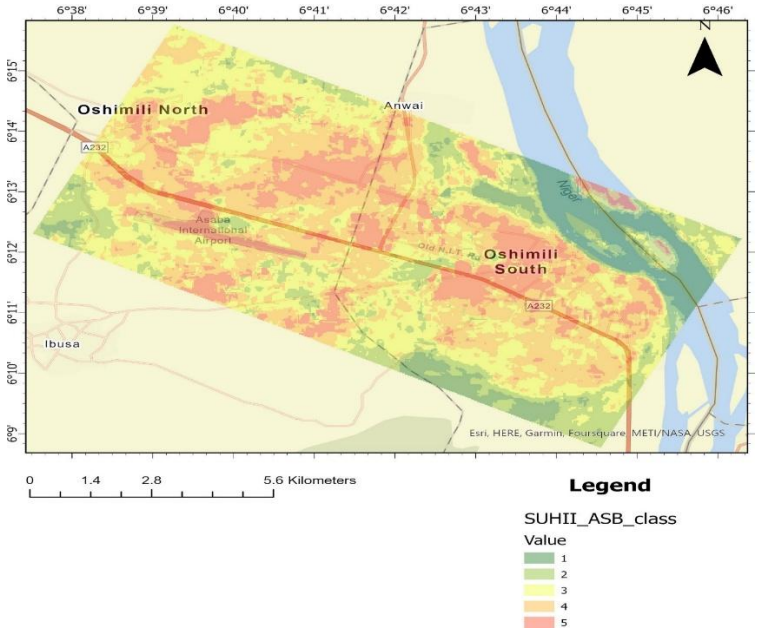

Figure 2: Surface Urban Heat Intensity Class for years, 2020 -2022 within Benin Metropolis

The surface urban heat Intensity Class for years, 2020 -2022 within Calabar city in (Figure 3), revealed heat stress class within the study area as class 3, 4 and 5 heat class. With class 1 and 2 outside the city centre with temperature difference of 8.74^{0}C and urban heat stress intensity of 5.29-3.45^{0}C.

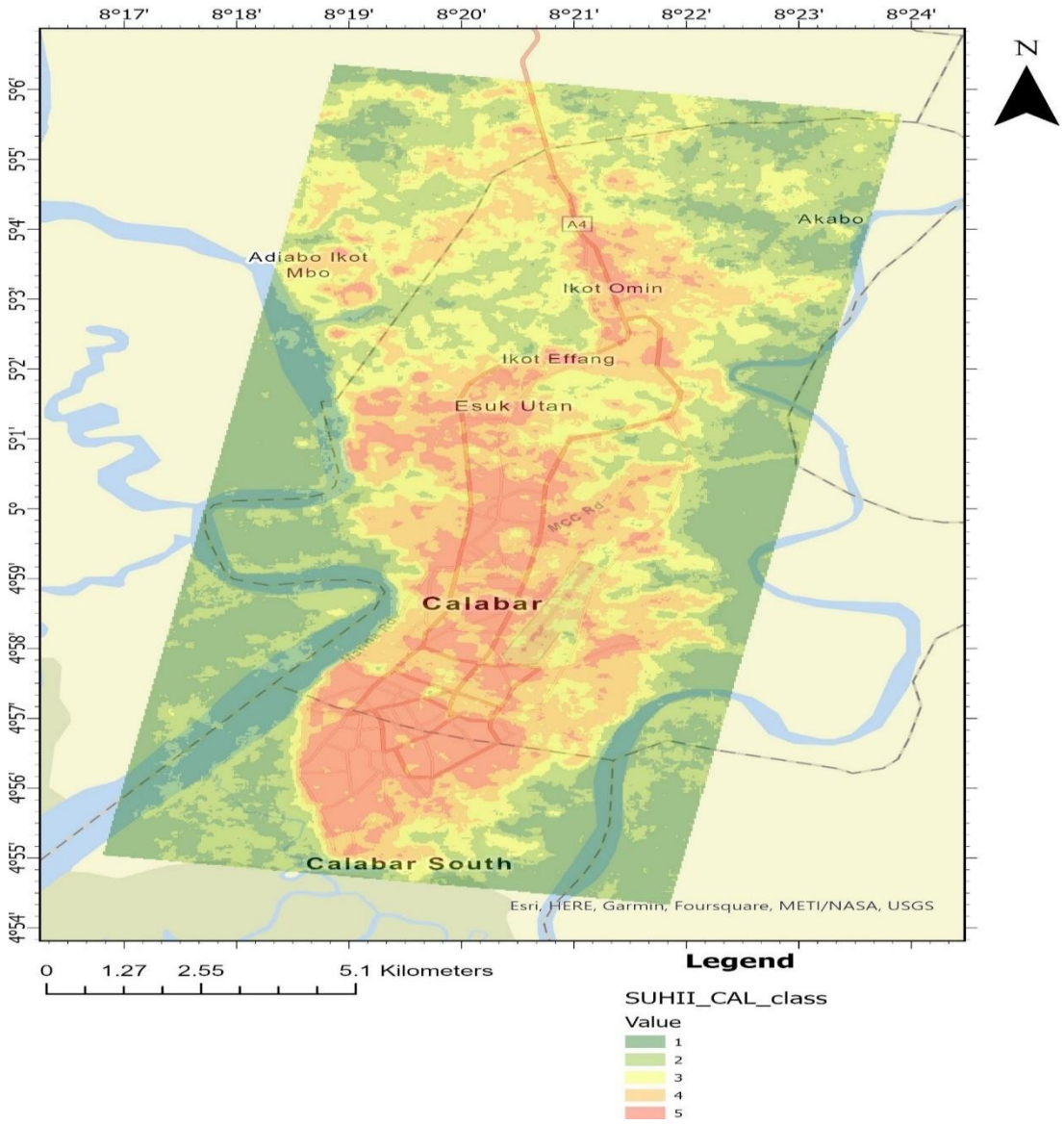

Figure 3: Surface Urban Heat Intensity Class for years, 2020 -2022 within Calabar Metropolis

The surface urban heat Intensity Class for years, 2020 -2022 within Owerri city in (Figure 4), revealed heat stress class within the study area as class 3, 4 and 5 heat class. With class 1 and 2 found outside the city centres with temperature difference of 10.15 ^{0}C and urban heat stress intensity of 3.88 -4.27^{0}C. Compared with classes moderate weak heat stress 0.08 -0.12^{0}C, moderate 0.13 -0.15^{0}C strong heat stress 0.16-0.19^{0}C and very strong heat stress with temperature values of 0.19-.036^{0}C. some areas within the city falls within the class 3 which is moderate heat class.

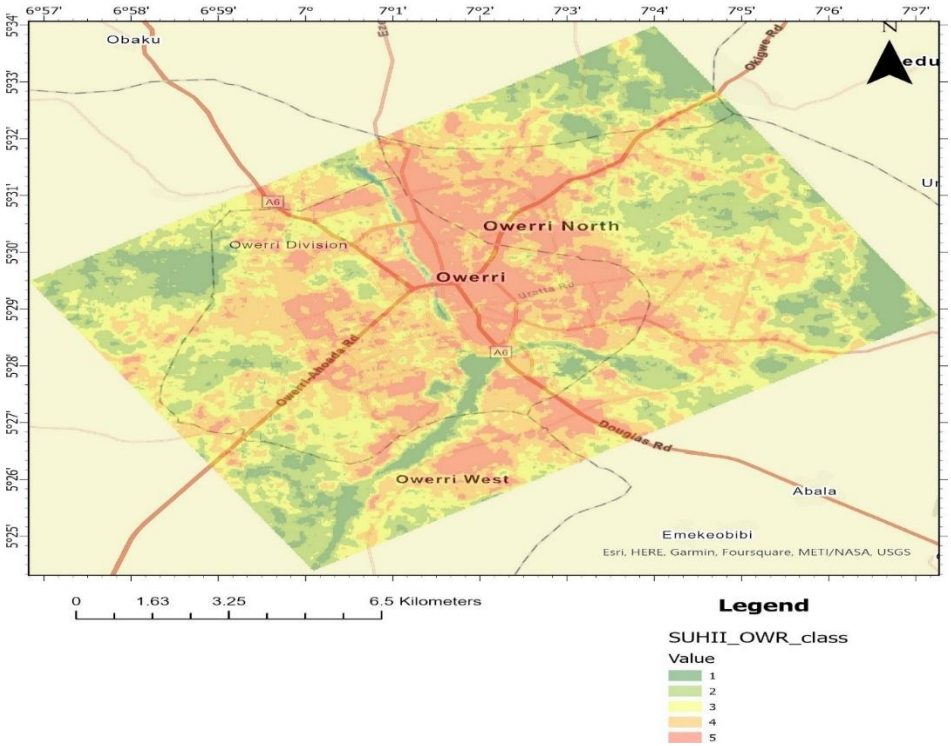

Figure 4: Surface Urban Heat Intensity Class for years, 2020 -2022 within Owerri Metropolis

The surface urban heat Intensity Class for years, 2020 -2022 within Port Harcourt city in (Figure 5), revealed heat stress class within the study area as class 2, 3, 4 and 5 heat class. With class 1 occurring outside the city centres, the with temperature difference of 11.99^{0}C and urban heat stress intensity of 5.89 -6.10^{0}C. Compared with classes moderate weak heat stress 0.08 -0.12^{0}C, moderate 0.13 -0.15^{0}C strong heat stress 0.16-0.19^{0}C and very strong heat stress with temperature values of 0.19-.036^{0}C. some areas around the city falls within the class 3 which is moderate heat class and class 2 with week heat stress.

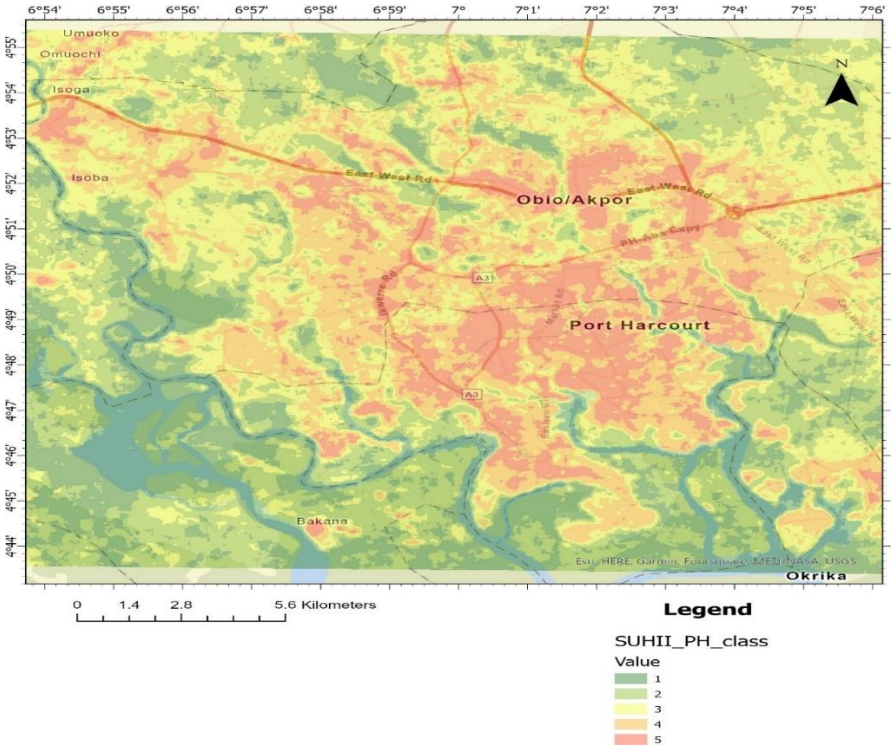

Figure 5: Surface Urban Heat Intensity Class for years, 2020 -2022 within Port Harcourt Metropolis

The surface urban heat Intensity Class for years, 2020 -2022 within Uyo city in (Figure 6), revealed heat stress class within the study area as class 3, 4 and 5 heat class. With class 1 and 2 occurring outside the city centre, the with temperature difference of 11.99^{0}C and urban heat stress intensity of 3.69-3.99 ^{0}C. Compared with classes moderate weak heat stress 0.13-0.15^{0}C, strong heat stress 0.16-0.19^{0}C and very strong heat stress with temperature values of 0.19-.036^{0}C.

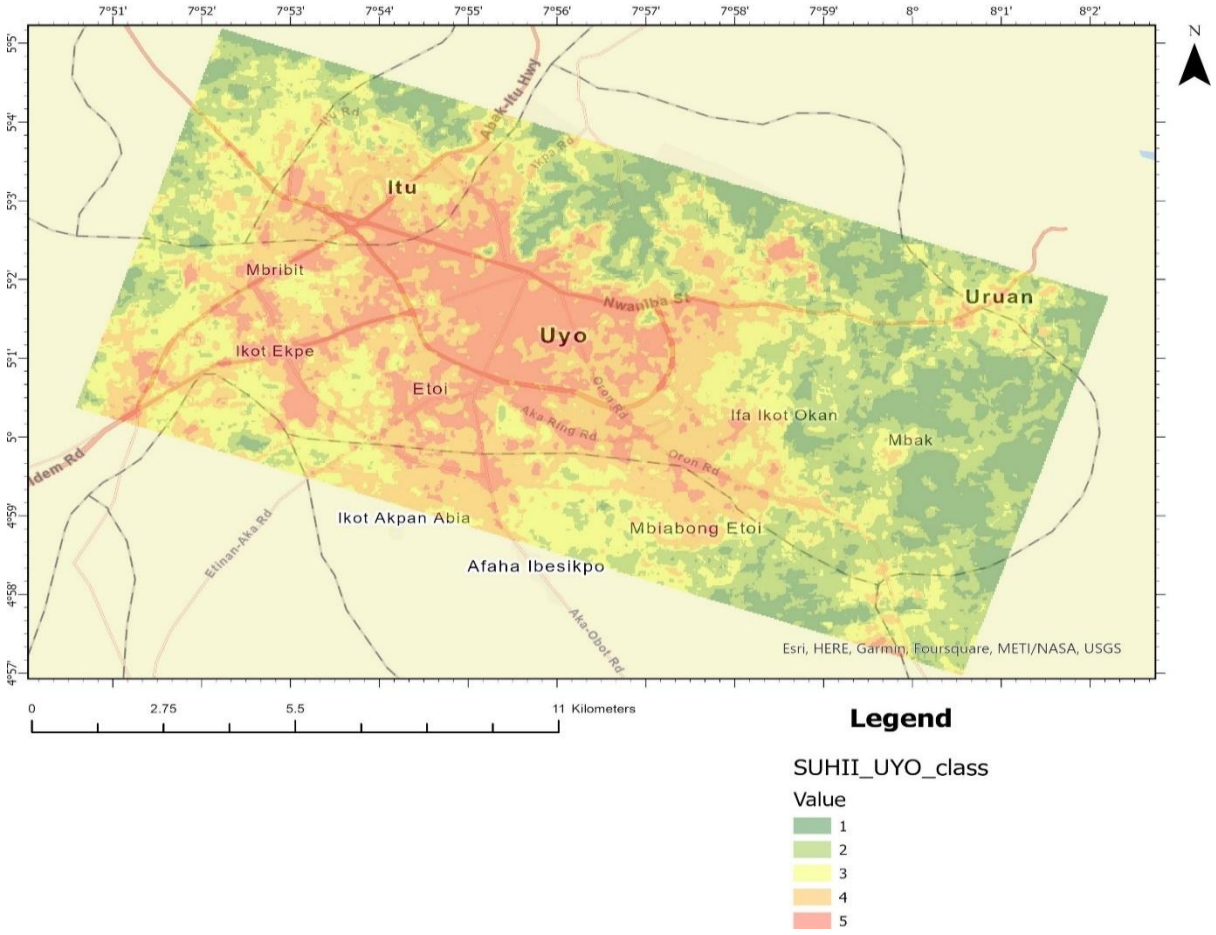

Figure 6: Surface Urban Heat Intensity Class for years, 2020 -2022 within Uyo Metropolis

The surface urban heat Intensity Class for years, 2020 -2022 within Yenagoa city in (Figure 7), revealed heat stress class within the study area as class 3, 4 and 5 heat class. With class 1and 2 occurring outside the city centres, the with temperature difference of 13.15^{0}C and urban heat stress intensity of 5.12-8.03^{0}C. Compared with classes moderate weak heat stress 0.08 -0.12^{0}C, moderate 0.13 -0.15^{0}C strong heat stress 0.16-0.19^{0}C and very strong heat stress with temperature values of 0.19-.036^{0}C.

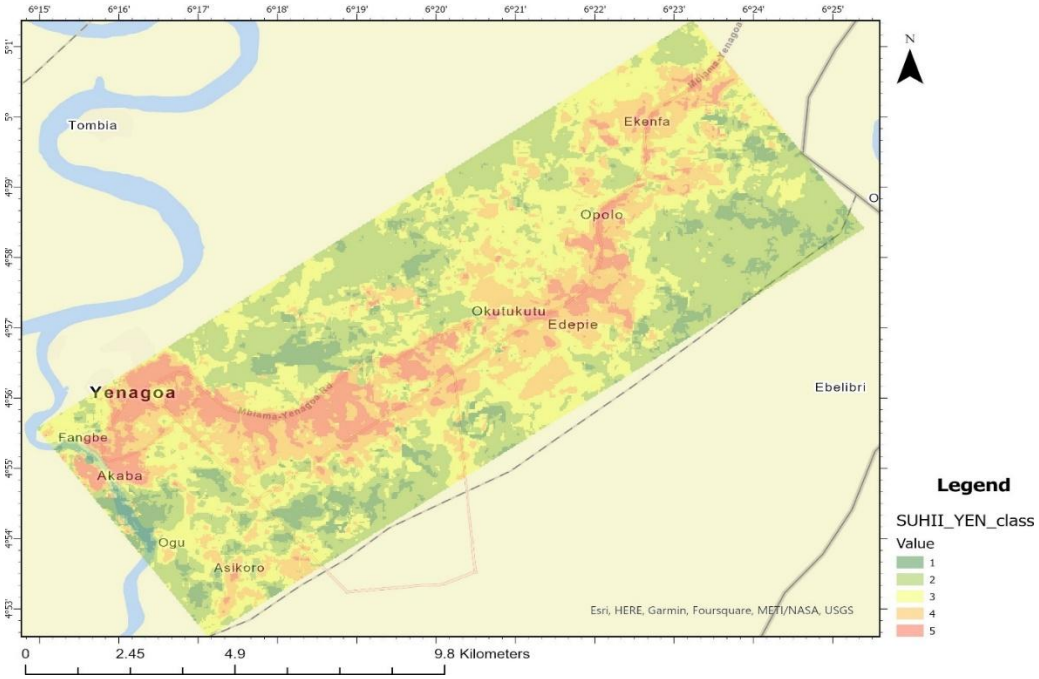

Figure 7: Surface Urban Heat Intensity Class for years, 2020 -2022 within Yenagoa Metropolis

The surface urban heat Intensity Class for years, 2020 -2022 within Benin city in (Figure 8), revealed heat stress class within the study area as class 3, 4 and 5 heat class. With class 1and 2 occurring outside the city centres, with temperature difference of 10.70^{0}C and urban heat stress intensity of 3.0-7.59 ^{0}C. Compared with classes weak heat stress 0.08 -0.12^{0}C, moderate 0.13 -0.15^{0}C strong heat stress 0.16-0.19^{0}C and very strong heat stress with temperature values of 0.19-.036^{0}C.

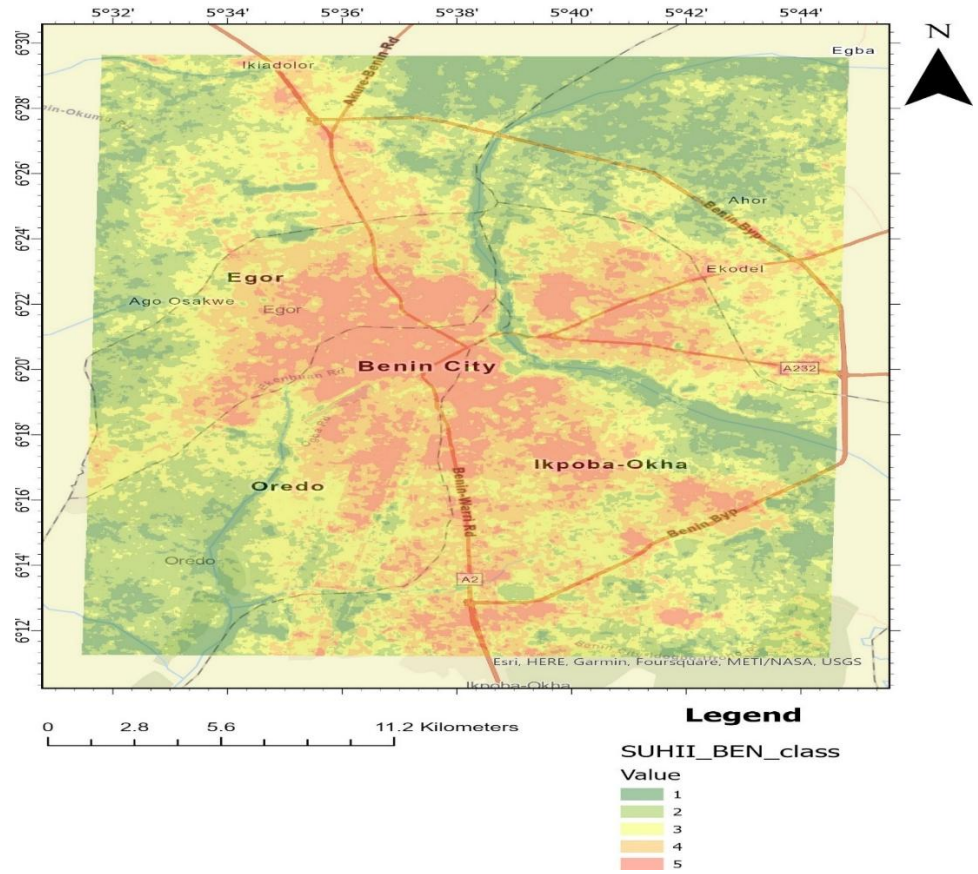

Figure 8: Surface Urban Heat Intensity Class for years, 2020 -2022 within Benin Metropolis

Population affected by Heat Stress in the Niger delta
Table 1 presents the population at risk of thermal stress in the urban centres of the Niger delta region. Heat exposure is also associated with several non-fatal health outcomes, including heat strokes, dehydration, loss of labor productivity, and decreased learning all these are the Characteristics of the built environment (Pörtner, Roberts, Adams, Adelekan, Adler & Adrian,2022). The population at risk of urban heat related issues in Port Harcourt city is around 416,921 persons, Benin has larger population at risk of class 5 heat issues with a population of 538,245 persons, Owerri 151,490, Calabar 133,535, Uyo city about 121,076 Yenagoa 75,876 and Asaba with population of 65,393 persons at risk of urban heat stress class 5. The population of 167,469, Calabar 162,224, Benin 473,148, Yenagoa 124,451 and Asaba population of 108,653 persons will be affected by heat related issues.

Though the cities have varying heat stress issues but a population of 404,300 within Port Harcourt will be affected by class 3 heat issues, Benin 369,936, Uyo 133,652, Yenagoa 96.045, Calabar 97,949 and Asaba 68,274 persons are at risk of urban heat stress. Calabar population at risk of class 2 heat stress is about 31,075, Benin 201,380, Port Harcourt city 135,854, Owerri 38,521, Uyo metropolis about 82,481, Yenagoa 26,850 and Asaba 17,369 persons are at risk of exposure to urban heat stress related issues, while 22,187 persons are at risk of class 1 urban heat stress within Port Harcourt city. Yenagoa population at risk is about 4,891, Owerri7,466, Uyo17,513 Calabar 3,176, Benin 19,128 and Asaba 2,316 persons stand at risk of exposure to urban heat stress class 1 combination of hot temperature and high humidity (high heat stress) has severe impacts on environment, society, and public health, especially in urban areas where the majority of the world's population lives. Heat stress describes the combined effect of high temperatures and humidity, posing severe impacts on human society and environment, especially in populated urban areas (Luo & Lau,2018).

Table: Total Population at Risk of heat stress in the study area.

Class	PH	YEN	OWR	UYO	CAL	BEN	ASB
1	22,178	4,891	7466	17,513	3,176	19,128	2,316
2	135,854	26,850	38,532	82,481	31,075	201,380	17,369
3	404,300	96,045	94,639	133,649	97,949	369,936	68,279
4	683,600	124,451	167,213	167,469	162,224	473,148	108,653
5	416,921	75,876	151,490	121,076	133,535	538,245	65,393

Source: UNPD 2020 estimates

IV. DISCUSSION OF FINDINGS

The surface urban heat intensity class within the cities in the Niger Delta region showed distinctive heat class as very week heat stress, weak, moderate, strong and very strong heat stress according to Janin *et al.* (2019). The cities within the Niger Delta regions generally falls within the urban heat stress class of 3 – 5 heat stress, however some cities in the study area have class 1 and 2 very close to the urban area immediately after the entrance into some of the cities. Residing in urban centre can expose large population people to urban thermal stress. This can in turn increase the risk of some health outcome. Large population of people live in the urban centres in the Niger Delta region of Nigeria. these large urban populations ranged from people of different races, colours, cultures and even ages looking for greener pastures in the urban centres, none of them is spared by urban heat menace. Table 1 displays large population of people affected by urban heat stress in Port Harcourt city, Benin, Asaba, Uyo, Owerri and Calabar, however majority of these populations may be ignorant of the heat stress phenomenon while others know about heat stress as several heat stress studies of urban centres have been conducted in other parts or regions of Nigeria. combination of hot temperature and high humidity (high heat stress) has severe impacts on environment, society, and public health, especially in urban areas where the majority of the world's population lives. Heat stress describes the combined effect of high temperatures and humidity, posing severe impacts on human society and environment, especially in populated urban areas.

V. CONCLUSION AND RECOMMENDATIONS

This study has effectively classified the intensity of urban heat stress and identified the population affected by heat stress in the Niger Delta region. The findings reveal a significant correlation between urbanisation, land use changes, and the increasing intensity of heat stress. Areas with high population densities and extensive built environments are more susceptible to elevated heat stress levels. The analysis shows that urban heat stress adversely impacts public health, exacerbating heat-related illnesses and reducing overall quality of life. The spatial distribution of heat stress intensity indicates that major urban centers, such as Port Harcourt, Benin city, Yenagoa, Uyo, Asaba etc. experience the highest levels of heat stress. These findings highlight the need for targeted interventions in these areas to mitigate the adverse effects of heat stress on the population. Furthermore, the study underscores the importance of incorporating heat stress mitigation strategies into urban planning and development policies to create more resilient and sustainable cities in the Niger Delta region. The cities under study exhibited different temperature characteristics as the heavily developed and industrialised tend to have temperature class 4 and 5 in most of the sampled area, while some have heat stress or intensity higher than the others, some showed parallel temperatures models with the city, some have wide distribution of class 4 temperature at the city centre and outside the city. Populations at risk of heat stress vary from city to city according to the nature of development in the studied states, the heavily urbanized have more people at risk of temperature class 5, while some parts of the city have population at risk of heat stress 4 ,5 and 3 class. However, recommendations have been made on how to mitigate the heat stress and create comfortable cities within the Niger Delta Region which includes:

1. Urban developers, infrastructural policymakers like the ministry of urban planning and development should ensure effective control of unplanned urban expansion in already built-up or undeveloped areas of the urban centres in the Niger delta.
2. Urban Planning and Green Infrastructure: Incorporate green spaces, parks, and urban forests into city planning to reduce urban heat islands. Increasing vegetation can help cool urban areas, enhance air quality, and improve the overall urban microclimate.
3. Sustainable Building Practices: Promote the use of sustainable building materials and designs that minimize heat absorption and enhance natural ventilation. Implementing reflective roofing and energy-efficient buildings can significantly reduce indoor heat stress.
4. Public Awareness and Education: Government should conduct awareness campaigns to educate the public about the risks associated with heat stress and the importance of preventive measures. Encourage community participation in heat stress mitigation efforts.
5. Heat-Resilient Infrastructure: Develop infrastructure that can withstand high temperatures, such as heat-resistant roads and public transportation systems. Ensure that public facilities, especially healthcare centers, are equipped to handle heat-related emergencies.
6. Heat Stress Monitoring and Early Warning Systems: Establish robust heat stress monitoring networks and early warning systems to provide timely information to residents and authorities. This can help in preparing for heatwaves and reducing heat-related health risks.

By implementing these recommendations, policymakers, urban planners, and community stakeholders can work collaboratively to reduce urban heat stress, improve public health outcomes, and enhance the resilience of cities in the Niger Delta region against the growing challenges of climate change.

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